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A novel research methodology for supply network collaboration management

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ABSTRACT

A supply chain has a multi-stage complex topological structure that is reconfigured dynamically and evolves over time. These features represent great challenges to supply network collaboration management. This paper proposes a novel research methodology for supply network collaboration research, including a methodological basis, a procedure model, and a conceptual decision-making model. The methodology integrates a three-dimensional flow model with a SCOR (Supply chain operations reference model)-based process modeling approach, a multi-agent system, distributed simulation technology and a three-dimensional decision-making model to support supply network analysis, modeling, standardization, development, implementation and decision making. This method creatively uses material, information and time flows as the research objects, combines process-oriented and agent-oriented modeling approaches and integrates multiple models, approaches and technologies to reduce research assumptions and constraints while improving the quality of research findings. The case for a five-stage make-to-order (MTO) supply network is studied for the application of the methodology and to verify its effectiveness.

1. Introduction

A supply network is a complex system emerging from the self-organization of heterogeneous member enterprises based on their interaction and collaboration. This network is no longer a single chain but is a network intertwined with several chains [10,25,31,46]. The network has a more complicated structure and a greater uncertainty than a single chain. In the network, information is asymmetric, resources are partially shared, and all members make decentralized decisions for their own interests in the face of uncertain demands. They are bound to affect the overall performance of the supply network and pose great challenges to supply network collaboration management. Supply network collaboration considers the overall performance. It is an effective means to fulfill the maximum interests of members by using advanced methods and technologies to coordinate the members' activities of sourcing, storage, production and delivery in a dynamic and partial information sharing context.

Currently, supply network collaboration is a hot topic. A volume of literature has been written concerning this hot topic. There are strategic, tactical and operational collaboration. Most of them focus on single-stage or two-stage supply networks using static analytical models. These studies are deficient in modeling and analyzing the dynamic evolutions of multi-stage supply networks, for example, the studies of Feng, Zhou, and Lai [11], Xu and Fan [47], Li, Lv, and Guan [23], and Eksoz, Mansouri, and Bwirlakis [9]. The current literature mainly uses the control theory approach, operational research approach, and game theory based on the research assumptions and constraints, resulting in a weak value for their research findings in practical applications, for example,

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the studies of Zhang et al. [51], Che and Chiang [8], Yan and Li [49], Sarrafha et al. [38], and Pasandideh, Niaki and Asadi [32]. Supply network collaborative processes inevitably involve material, information and time flows. The effective management of these flows and collaborative decision-making based on these flows are the key to success for the supply network [48]. Current literature has not considered multi-dimensional flows in the supply network collaboration research. Therefore, it is critical for researchers to build a virtual dynamic evolution model that considers multiple flows of a multi-stage supply network with fewer research assumptions and constraints. It needs an efficient research methodology to support this research.

This paper proposes a novel research methodology for supply network collaboration management. The methodology integrates a three-dimensional flow model with a SCOR-based process modeling approach, a multi-agent system and distributed simulation technology to build a research methodological framework. The framework outlines a multi-phase procedure model that experiences three-dimensional flow modeling, standard SCOR process refinement, and multi-agent system development. Then, a system-distributed simulation is performed until the final decision-making is formulated. The methodology creatively uses three-dimensional flows as the objects, combines process-oriented and agent-oriented modeling approaches, and adopts a distributed simulation to support three-dimensional decision-making. The integrated methodology has a novel perspective in theory and provides an effective means and an important reference for conducting supply network collaboration management in practice.

The rest of this paper is organized as follows. Section 2 presents a series of related work. Section 3 proposes a novel research methodology for supply network collaboration management. Section 4 provides a case study using the proposed methodology. Section 5 presents the paper's conclusions.

2. Related work

Supply network collaboration can improve the overall performance of the supply network. A volume of literature has studied supply network collaboration at the strategic, tactical, and operational levels, such as collaborative planning research [16,17], collaborative production research [40,52], collaborative inventory research [2,6], collaborative transportation research [5,7,22], collaborative distribution research [40,51], collaborative inventory and transportation research [37], collaborative inventory, production and transportation research [29], collaborative forecasting research [3,9,12,13,21], and knowledge integration in collaborative supply chains [20]. Most of these studies focus on single-stage or two-stage supply networks and build static analytical models, resulting in a weak value for their studies findings in practical applications. Considering the dynamic evolutions of supply networks over time, Wei and Hu [44] explored a collaboration mechanism in a mobile supply chain of the manufacturing industry based on life cycle. Trappey et al. [43] applied system dynamics modeling to simulate and identify product carbon footprint life cycles for collaborative green supply chains. However, there are very few studies in this area. It is urgent that we systematically conduct in-depth studies of multi-stage supply network collaboration by considering their dynamic evolutions.

The current studies regarding supply network collaborative decision making mainly adopt the control theory approach, operational research approach, and game theory. Fasli and Kovalchuk [10] explored the neural networks (NN) and genetic programming (GP) learning techniques for developing successful seller strategies in dynamic supply chain management. Pasandideh, Niaki, and Asadi [32] used a non-dominated sorting genetic algorithm (NSGA-II) and a non-dominated ranking genetic algorithm (NRGA) to solve a bi-objective deterministic mixed-integer nonlinear programming model for a multi-product multi-period three-echelon supply chain problem in uncertain environments. Han et al. [14] proposed a general linear multi-follower tri-level (MFTL) decision model for a reference-based uncooperative MFTL decision problem and developed a MFTL Kth-Best algorithm to find an optimal solution to the model. Zhang et al. [51] proposed a modified multi-criterion optimization genetic algorithm for order distribution in a collaborative supply chain. Sadeghi, Sadeghi, and Niaki [37] proposed an improved particle swarm optimization algorithm to optimize a hybrid vendor-managed inventory and transportation problem with fuzzy demand. Galbreth, Kurtulus, and Shor [12] provided an analytical perspective on the link between supply chain collaboration and forecast accuracy, showing that collaborative forecasting can lead to less accurate demand forecasts over a wide range of cost and demand parameters. Theissen and Spinler [42] built an analytic network process (ANP) model for collaborative CO_2 reduction management through the strategic analysis of manufacturer-supplier partnerships. Che and Chiang [8] adopted the analytic hierarchy process and genetic algorithm with cycle-time estimation for a collaborative supply chain plan design. Alemany et al. [1] built mathematical programming models for the temporal and spatial distributed decision-making processes in supply chain collaborative planning. Wu et al. [45] developed a stochastic fuzzy multi-objective programming model for supply chain outsourcing risk management in presence of both random uncertainty and fuzzy uncertainty. Bhattacharya et al. [4] proposed a collaborative decision-making approach using a fuzzy analytic network process (ANP)-based balanced scorecard for green supply chain performance measurement. Rodger [35] studied the application of a fuzzy feasibility Bayesian probabilistic estimation of supply chain backorder aging, unfilled backorders, and customer wait time using stochastic simulation with Markov blankets for collaborative decision making. Rodger, Pankaj and Gonzalez [36] used a fuzzy induced linguistic ordered weighted averaging approach for the decision support evaluation of backorder risk in a supply chain. Zhang, Shang, and Li [52] proposed an integrated solution framework combining scatter evolutionary algorithm, fuzzy programming and stochastic chance-constrained programming for the collaborative production planning of a supply chain under price and demand uncertainty. Lu, Lau, and Yiu [30] proposed a hybrid algorithm that integrates Lagrangian relaxation and an immunity-inspired coordination scheme for collaborative decision-making in a decentralized supply chain. Zamarripa et al. [50] used the mathematical programming and game theory optimization-based tool for supply chain planning in cooperative/competitive environments. Yan and Li [49] conducted a game analysis on the collaborative operation behavior in a logistics service supply chain. These methods for supply network collaborative decision making always